GRAN?

IN -46-CR

1

Final Report, March 31, 1992:
Viscoelastic Deformation Near Active Plate Boundaries
NASA/CDP NAG 5-750
Steven N. Ward
Institute of Tectonics
University of California, Santa Cruz

3P

The bulk of the research products sponsored by the Crustal Dynamics Project are presented in three papers published in the *Journal of Geophysical Research*. These papers are abstracted below and included in their complete form in Appendices A-C.

North America-Pacific Plate Boundary, and Elastic-Plastic Megashear: Evidence from Very Long Baseline Interferometry, *JGR, 93*, 7716-7728, 1988.

I investigate a number of lithospheric deformation models based upon the concept that the motions of points near the North America-Pacific plate boundary are a linear combination of North America and Pacific velocities. This concept entails a shear strain transition zone in the vicinity of the boundary. The best of these models fit 95% of the variance in 139 Very Long Baseline Interferometry length and transverse velocity observations taken over 5.5 years and require only 90% of the relative plate motion predicted by RM2. Residual misfits in the megashear models are largely explained by a 6.1 mm/yr component of Basin and Range spreading perpendicular to the plate boundary. Instantaneous shear deformation associated with plate tectonics is apparently developing in a zone 450 km wide paralleling the San Andreas Fault. Some of this deformation will be recovered through elastic rebound; the rest will be permanently set through plastic processes. Thus depending on the elastic-plastic composition of the borderlands, the width and pattern of strain accumulation in the megashear over geological time may or may not be significantly different than what is currently observed. Because VLBI data have been assembled for only a small fraction of the earthquake cycle, plastic and elastic strains are indistinguishable. Other information will have to be brought to bear to discriminate elastic and plastic behaviors and reconcile instantaneous and geologic deformation near the North America-Pacific margin.

North America-Pacific Plate Motions: New Results from Very Long Baseline Interferometry, *JGR, 95*, 21,965-21,981, 1990.

Expansion and densification of the VLBI network by the NASA Crustal Dynamics Project continues to clarify details of Pacific-North America motions. In this paper I construct, for the first time, rigid plate tectonic models based purely on space geodetic data. Construction of VLBI plate models has the advantages of averaging the bias and errors of individual site velocities, making failures in the rigid plate assumption easy to document, and allowing the consistency of specified plate models to be quantified against the VLBI data set as a whole. VLBI-based rigid plate models VM2 and VM3, obtained by fitting vector velocities of 10 sites in the stable interiors of the North America and Pacific plates, reveal a misfit of VLBI observations and RM2 (*Minster and Jordan*, 1978) predictions significant at the 99% confidence level. NUVEL-1 (*DeMets et al.,* 1990)

reproduces the velocities of these 10 sites far better than RM2 and offers a fit to the data which is statistically indistinguishable from VM2 and VM3.

By including velocities of 16 additional stations in the deforming plate margin, VM2 and VM3 can resolve all four terms [$\mathbf{V}_{PN}$: Total Pacific-North America motion; $\mathbf{V}_{SA}$: San Andreas slip; $\mathbf{V}_{E,W}$: Path integrated deformation east and west of the San Andreas] in the vector equation characterizing Pacific-North America plate boundary deformation

$$\mathbf{V}_{PN} - \mathbf{V}_{SA} = \mathbf{V}_E - \mathbf{V}_W$$

for several points along the San Andreas without reference to a global plate model, geological or local geodetic measurements, or restrictions on distributed shear. In most cases, instantaneous VLBI-determined rates agree with geologically-based estimates. Mapped to point C (36.0° N, 120.6° W) in central California, VM2 gives $\mathbf{V}_{PN}$(C)= 46.8±1.4 mm/y (N36°±2°W), $\mathbf{V}_{SA}$(C)= 38.6±1.3 mm/y (N36°±2°W), and $\mathbf{V}_E$(C)= 8.2±1.3 mm/y (N34°±7°W). VLBI substantially eliminates $\mathbf{V}_W$(C), the component of the San Andreas Discrepancy west of C, although a few mm/y of right lateral strike slip on offshore faults can not be rejected. At point D (34.1°N, 117.0°W) in southern California, VM2 returns $\mathbf{V}_{SA}$(D)= 25.0±1.1 mm/y (N52°±3°W), $\mathbf{V}_E$(D)= 8.8±1.1 mm/y (N25°±8°W), and $\mathbf{V}_W$(D)= 13.3±1.6 mm/y (N21°±5°W). $\mathbf{V}_W$(D) is accommodated west of the San Andreas to the Channel Islands. The azimuth of San Andreas slip suggests that the transverse ranges north of Los Angeles are absorbing 8±1 mm/y of compression perpendicular to the trend of the fault.

Eurasia Plate Motions from Very Long Baseline Interferometry, *JGR*, (submitted), 1992.

VLBI network data complete through late 1990 find that instantaneous Pacific-North America plate motions continue to agree with NUVEL-1 but that Eurasia-North America instantaneous rates are 5 more southerly and 12% slower. Other inferences from the latest VLBI measurements include: a clarification of the northern limit of shear deformation associated the western North America Borderland, convergence across the Alps, eastward escape of southeast China in response to the indentation of India, and accumulation of permanent and earthquake-related elastic strain in Japan.

Related Publications Supported by this Project

Ward, S.N. and G.R. Valensise 1989. Fault Parameters and Slip Distribution of the 1915, Avezzano, Italy Earthquake derived from Geodetic Observations, *Bull. Seism. Soc. Am.*, 79, 690-710.

Barrientos, S.E. and S.N. Ward, 1990. The 1960 Chile Earthquake: Inversion for Slip Distribution from Surface Deformation, *Geophys. J. Int.*, *103*, 589-598.

Valensise, G. and S.N. Ward, 1991. Long-Term Uplift of the Santa Cruz Coastline in Response to Repeated Earthquakes along the San Andreas Fault, *Bull. Seism. Soc. Am.*, in press.

Ward, S. N., 1991. Synthetic Seismicity Models for the Middle American Trench, *J. Geophys. Res.*, 19,800-19,810.

Appendices:

A: Ward, S. N., 1988, North America-Pacific Plate Boundary, and Elastic-Plastic Megashear: Evidence from Very Long Baseline Interferometry, *J. Geophys. Res., 93*, 7716-7728.

B: Ward, S.N., 1990. North America-Pacific Plate Motions: New Results from Very Long Baseline Interferometry, *J. Geophys. Res., 93*, 21,965-21,981.

C: Ward, S.N., 1992. Eurasia Plate Motions from VLBI, *J. Geophys. Res.*, submitted.